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Addis Ababa Science and Technology University

University for the Industry

ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLEGE OF ARCHITECTURE AND CIVIL ENGINEERING

POST GRADUATE STUDY

HANDLING OF CONCRETE MAKING AGGREGATES:-THE CASE OF ADDIS ABABA CITY ROADS AUTHORITY

An Independent Project submitted to college of architecture and civil engineering post Graduate Studies of Addis Ababa Science and Technology University in Partial fulfillment of the requirements for the Degree of Master of Engineering in Civil Engineering (Construction Technology and Management).

BY

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ADDIS ABABA, ETHIOPIA

ADDIS ABABA SCIENCE AND TECHNOLOGY UNIVERSITY

COLLEGE OF ARCHITECTURE AND CIVIL ENGINEERING

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By

Kebede Tafa

BSc in Civil Engineering

Date of Defense: March 1, 2017

Approved by Board of the Examiners

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Acronym

AACRA=Addis Ababa City Road Authority

AASHTO=American Association of State Highway and Transportation Office

ASTM=American Society for testing and material

BS=British Standard

ERA=Ethiopia road authority

GDP =Gross Domestic Product

LA=Loss of Abrasion

FI=Fineness Index

F.M =Fineness Modulus

SME=Small & Middle Enterprises

Abstract

Construction materials management is an important element in the management of construction projects. One of the construction materials widely used in construction projects is Aggregate. Aggregate being one of the important ingredients of many of the construction materials, in addition to its subjectivity to variability, requires a close and thorough care and handling in construction projects. The aggregates, which majority of them occurs naturally, are subjected to a wide range of variability and quality problems. Therefore, with this respect a Case Study is conducted to assess the situation of handling of concrete making aggregate in the Addis Ababa City Road Authority (AACRA) construction projects with a special emphasis given to the material making aggregates. The objective of the Case study is to identify the current situation of the handling of concrete making aggregates and its production process in the AACRA construction projects in general. Also, the goal of this paper is to give recommendation in line with the outcome of the results of the case study. Therefore, in the material test results of fine aggregate, coarse aggregate and rock samples were collected from AACRA quarry sites and analyzed. Moreover, the case study is carried out in different parts of Addis Ababa City Road Authority's quarry sites that were also showed me that the naturally available materials have quite acceptable quality to be used as an aggregate making material. The Case Study is also indicated that the reason why aggregate making materials fail to comply with requirements attributes to the handling of the materials in the construction industry but not to the unavailability of materials satisfying requirements in construction projects. Further, from my observations that made in this construction sites and aggregate production plants in addition to the interviews were made with relevant personnel, that lead me to concluded my case study that the aggregate production in Addis Ababa is my expected result shown in the AACRA standards of materials with respect to quality, quantity and production process. The conclusion drawn from this case study is an aggregate production process and handling of concrete making aggregate in the AACRA construction projects that provides a lesson gained from my case study.

***Key words**: Fine aggregate, coarse aggregate, test, handling, quality, production*

Chapter One:-Introduction

1.1. Background

The construction activity accounts for 6-9% of the Gross Domestic Product (GDP) of many countries. In addition, the total annual value of construction works in the world ranges from 1-1.5 trillion dollars. It is also believed that construction accelerates the economic growth of a nation. However, there is a vast scope for improving performance through knowledge in the construction industry, where men, materials, machinery, money and management work together to build a facility [6].

It is a known fact that, resource planning and management is one of the most important parameters for competitiveness and profitability in today's construction technology. One important aspect of resources management is management of construction materials in construction projects [4].

Good project management in construction must vigorously pursue the efficient utilization of labor, material and equipment. Improvement of labor productivity should be a major and continual concern of those who are responsible for cost control of constructed facilities.

Material handling, which includes procurement, inventory, shop fabrication and field servicing, requires special attention for cost reduction with acceptable standard quality [6].

Materials management is defined as the management system for planning and controlling all the necessary efforts to ensure that the right quality and quantity of materials and installed equipments are appropriately specified in a timely manner, and obtained at a reasonable cost, and is available when needed. Especially, management of construction materials is generally recognized to be the integrated coordination of materials takeoff, purchasing, expediting, receiving, ware housing, proper utilization and disposal. When these functions are not properly managed, materials shortages, surpluses, and cash flow problems are likely to occur.

Costly labor delays result when the required quantity and quality of construction materials are not available when needed [5].

Materials management is an important element in project planning and control. In construction projects, materials account for more than 40% of the project cost. A small saving in materials cost, say even 5%, through efficient management of materials, can result in a large contribution specially, when competitive bidding is for small profit margins, varying from 3.5% to 10% of the project cost

[1]. A research carried out in Ethiopia had shown that construction materials constitute 57% of the total budget allocated for construction works [8].

Broadly, the term 'materials' denotes all purchased items utilized at the project site including construction materials, supporting plant and equipment, and administrative facilities and stores. Construction materials cover all types of materials used in construction including electrical and mechanical fittings, fixtures, devices and instruments that are incorporated during the construction of permanent works and temporary supporting works at site [6].

The materials for delivery to and from a construction site may be broadly classified as: (1) bulk materials, (2) standard off-the-shelf materials, and (3) fabricated members or units.

Bulk materials refer to materials in their natural or semi-processed state, such as earthwork to be excavated, wet concrete mix, gravel, sand etc. that are usually encountered in large quantities in construction. Standard piping and valves are typical examples of standard off the-shelf materials. Fabricated members such as steel beams and columns for buildings are pre-processed in a shop to simplify the field erection procedures [6].

It is a known fact that, construction materials management in construction projects in Ethiopia is done usually by experience and using traditional methods. It is also viable that lack of proper construction materials management system in the country contributes to the high construction cost and poor quality of construction products in Ethiopia. Researches have indicated that lack of proper materials management is one of the causes of claims in Ethiopia.

Therefore, the mentioned issues signify the need to develop an effective constructions materials management system in construction projects in Ethiopia in general and handling of concrete making aggregates in the construction industry in particular with an ultimate result of a completed project with good quality and within the schedule.

1.2. Objective of the study

Objectives:-

General objective:-

- To identify the current situation of handling of concrete making aggregates and its production process in the AACRA construction projects.

Specific Objectives:-

- To identify the current situation of the handling of concrete making aggregates in the AACRA construction projects.

- To assess the situation of aggregates production process in the AACRA construction projects.
- To indicated that the reason why concrete making aggregates fail to comply with requirements attributes to the handling of the materials in the construction industry.

Chapter Two:-Literature Review

2.1. Introduction

In a concrete mixture the aggregates which are generally graded in size from fine to pebbles or crushed stones, form the inert mineral filler material which the cement paste binds together. These aggregates generally occupy 65 to 75 percent of the volume of concrete. In choosing aggregate for use in a particular concrete attention should be given, among other things, to three important requirements [18].

Workability when fresh for which the size and gradation of the aggregate should be such that undue labor in mixing and placing will not be required.

Strength and durability when hardened- for which the aggregate should:-1) Be stronger than the required concrete strength 2) Not contain impurities which adversely affect strength and durability of the concrete 3) Not go into undesirable reaction with the components of cement 4) Be resistant to weathering action

Economy of the mixture- meaning to say that the aggregate should be: - 1) Available from local and easily accessible deposit or quarry 2) Well graded in order to minimize paste, hence cement requirement.

Cement is the most expensive of the materials used to make concrete. For this reason and because the aggregates provide a relatively cheap filler, it is advisable to use as much aggregates as a given amount of paste will bind together. In addition to being relatively cheap filler, the aggregates reduce the volume changes resulting from the setting and hardening process and from moisture change in the paste [18].

In order to provide a dense packing, or arrangement of particles in place, in a concrete mass, the aggregate must be suitably graded from fine to coarse. In general, the more aggregate that can be crowded into a given volume of concrete, the more economical is the resulting product.

On the other hand, with the given amount of aggregate per unit volume of concrete, the more workable a mix is as the result of suitable gradation - the lower the water requirement and the greater the strength [23].

2.2. Handling of Concrete Making Aggregates

Construction materials can be readily available naturally or pass through a manufacturing process to be used directly for construction purposes. It is usually easy to control the quality of construction materials that pass through a manufacturing process. However, it is very difficult to control the uniformity and quality of construction materials that are available naturally and used directly for construction purposes. This is usually true for concrete making materials especially for the aggregates.

Research carried in Addis Ababa has shown that over 50% increase in compressive strength can be obtained simply by using aggregates that have different physical properties, but having similar grading limit and silt content. The different aggregate types (fine and coarse) do not have appreciable cost differences but the magnitude of strength variation resulted is highly significant. Thus, the result depicts the economic advantage in concrete production by saving cement, which is the most expensive construction material in concrete production by selecting better quality aggregate, grading and keeping the silt content within the allowable limit [2].

Although many people view aggregates as just a product that is taken from a quarry, transported and used in a structure, this is far from the truth.

Aggregates are a low value product and therefore it is expensive to move the product.

The importance of aggregate gradation limits and the maximum aggregate sizes are well known. The grading and maximum sizes of aggregates affect relative aggregate proportions, as well as cement and water requirements, workability, economy, porosity, and shrinkage of concrete.

In order to control the quality of the aggregates, the trend of late has been to prescribe an end result specification. Specifications generally require “all aggregates to be handled and stored in such a manner that will minimize segregation, avoid contamination, and secure a uniform grading of the material within the specified gradation band”. This naturally places the responsibility for quality control in the hands of the contractor. Since contractors generally rely on commercial producers for the source of their aggregates, the responsibility essentially has been transmitted through the contractor to the material supplier.

The guidelines on recommended practices for handling aggregates should, if followed, result in maintaining quality of gradation and cleanliness characteristics.

The recommendations trace a path from the producer to the user in three broad areas:-A) Hauling to stockpile B) Stockpiling C) Unloading stockpiles and charging mixer

A. *Hauling to Stockpile*

The hauling of aggregates and sand from the point of production is usually by truck or rail; however, there are many circumstances where economics dictate that other modes or combinations be used.

Regardless of mode used, the possibilities of degradation, segregation and contamination arise each time the material is shipped:-1) Economics is the most important factor to consider when selecting the route and method of transportation. 2) Care must be exercised through all stages of transportation to avoid segregation of particle sizes and in some cases degradation.

Specific Suggestions

i) Transportation costs frequently are greater than aggregate costs except when nearby sources are available. ii) When designing a mix, consider alternates of transportation before selecting a source. iii) Tougher environmental rules and stricter regulations will cause sources to be located greater distances from built-up areas. iv) Designers should be aware of the difference in hauling costs when considering concrete and asphalt pavement designs.

B.Stockpiling

The method of stockpiling has a large effect on the variation in gradation and degradation characteristics of an aggregate. The most economical and acceptable method of forming and reclaiming stockpiles from aggregates delivered in trucks is to discharge the loads in such a way that they are rightly joined and to reclaim the aggregate with a front-end loader. When aggregates are not delivered in trucks, the least expensive acceptable results are obtained by forming the stockpiles in layers with a crane bucket and reclaiming the aggregates with a front-end loader. [16]

Concrete can be proportioned to permit use of a fairly wide variety of gradations, but excessive variations in grading may noticeably affect such properties as slump and cement efficiency. Deviation from the design, gradation, especially on the finer sieve, is particularly undesirable.

Smaller size aggregate pieces have greater surface area than larger ones. Consequently, when undersized particles are concentrated, through segregation or degradation, water demand is significantly increased.

Specific Suggestions

i. Cone type stockpiles should be avoided under all conditions. Many producers and contractors still tend to stockpile coarse aggregates by coning because of simplicity, even though the practice has demonstrated that segregation will invariably occur.

ii. Segregation is minimized when aggregate stockpiles are formed by spreading in thin layers to minimize gravity flow.

iii. If space is available, long flat stockpiles are considered desirable.

iv. Backing truckloads of aggregates onto the pile and dumping in close packed piles is most desirable from an economic stand point. Unfortunately, some materials will break down under this action while some will not provide traction to allow the trucks to pull up on the pile. In other cases, the stockpile terrain or size of the stockpile area prohibits the long gradual slopes essential for the success of this type of stockpiling; and other methods of stockpiling must be used.

v. Front end loaders used for stockpiling should have the widest tires available and should avoid following the same path every load.

vi. Economics should not be the final criteria for constructing stockpiles. Segregation, degradation and contamination problems should be avoided even if more costly. Contractors must do more toward seeing that their producers adhere to good stockpiling and handling practices. It is too late to do much about segregation and degradation after you have received the material.

vii. The average loss on a stockpile placed on an unpaved site is approximately 3 percent. This would indicate that paving of a site would be desirable from an economic angle. Usually local bituminous hot mix plants are available for this work. Cement treated sub-base and lean concrete mix can be used to pave the plant site. The great majorities of contractors do not pave but use a clean, cheap, local stone as a mat under their pile to minimize contamination by muddy soil.

viii. The effect of pollution requirements must be considered in the selection of stockpile areas.

ix. Water drainage from stockpiles due to rainfall or pre-wetting activities must be controlled or treated to meet pollution requirements.

x. When the contractor designs, the mix, consideration should be directed toward using a single coarse aggregate stockpile.

xi. A continuous sampling and testing program must be maintained to assure that material received meets gradation requirements and that stockpiling techniques are retaining these attributes. A control chart system using averages and ranges is an effective visual aid technique that can easily be instituted. This system will provide advance warning that the material being stockpiled may be out of specification and can provide a clue as to cause.

C. Unloading Stockpiles and Charging Mixer

Special attention should be given to unloading stockpiles and blending of materials on the charging belt in order to assure uniformity and homogeneity of the concrete produced. Research has demonstrated that segregation of the mix can result if proper blending of the materials is not accomplished prior to entry into the mixer.

<u>Specific Suggestions</u>

i. Care must be taken in unloading a stockpile to avoid segregation. One recommended technique is to have the front-end loader rake down the slope prior to filling the bucket.

ii. Blending can be accomplished by coordinating the rate of flow from each bin or from the individual compartments within a single bin setup. Where flow from separate bins is combined on the main belt leading to the mixer, blending techniques are relatively simple. In this case, the speed of individual belts is adjusted so that beginning and ending flow on each coincides. A belt scale system could be used to augment this blending method. Where batch portions for each size aggregate flow from individual compartments onto the main belt located below the bin, blending is more difficult to achieve. If it is possible to install a full width belt sampler installation on the main belt, information for making adjustments and for continuous monitoring of aggregate gradation is readily available. However, on most setups, space for such installation is not available, and an incremental belt sampling technique must be used.

Sieve analysis made on five or more samples obtained in this matter should provide sufficient information that blending is adequate, or adjustments are needed. Belt sampling requires that the loaded belt be stopped while the sample is taken, putting a severe strain on the system. The following sampling sequence will help alleviate this situation:-1) Open bin gates with belt running 2) Close bin gates at predetermined time 3) Empty material on belt into the mixer 4) Open bin gates for predetermined time (usually 2 to 4 seconds) 5) Close bin gates 6) Stop belt with all the incremental sample available for sampling 7) Obtain full belt width sample 8) Repeat same procedure for additional samples from batch.

A plot of aggregate gradation for several of the sieve sizes will provide visual information where adjustments are needed.

Therefore, the mentioned issues signify the need to develop an effective constructions materials management system in construction projects in Ethiopia in general and handling of concrete making aggregate in the construction industry in particular with an ultimate result of a completed project with good quality and within the schedule.

2.3. Aggregate Production

Aggregates are important construction materials, both for new constructions and maintenance works. Aggregates are valuable natural resource and it is our obligation to use these materials sensibly. To use aggregates for the intended purpose due attention should be given to the production process employed to get aggregate of the right quality.

The vast majority of materials used in the mineral aggregate industry are obtained from Surface-mined stone quarries or from sand and gravel pits. How materials are extracted influences their quality. Good understanding of the basic material properties, usage possibilities and quality are significant for sensible use of aggregate resources. Knowledge of material properties may aid in the selection of aggregates to ensure optimum use of the resource. For instance, high quality (and valuable) aggregate may be used for the more expensive constructions whereas aggregates with lower quality may be selected for massive fills where quality demands are not as such strict. In addition, unnecessary damages to the nature may be prevented, optimum exploitation of the resource may be achieved and environmental effects may be better estimated. Further, it is important for responsible parties to be up to date with locations and details of existing and potential quarries. The geology of material suitable for aggregates is highly variable and sources are widespread. However, not all rocks make good aggregates. Good aggregates must be hard and tough and shouldn’t not break down or disintegrate easily. In addition, the site for a quarry will depend on the suitability of the material, proximity to populated areas, transport costs, existing and planned land use, the impact on the environment and the rehabilitation of the site after quarrying operations have ended. Finally, possible sites are prospected thoroughly and core samples are taken to test for suitable aggregate products. The availability and supply of coarse aggregate from the currently identified and potential sources is influenced by a number of factors, such as cost of transport, competing land uses, and the environmental impacts of extraction and transport. Therefore, it is imperative that a strategy for sourcing and transporting large quantities of aggregate from outside the region be adopted for future management of identified and potential concrete aggregate resources.

2.4. Functions of the Aggregates

The aggregates have three principal functions:-1) To provide a relatively cheap filler for the cementing material; 2) To provide a mass of particles which are suitable for resisting the action of applied loads, abrasion, the percolation of moisture, and the action of weather; and 3) To reduce the volume changes resulting from the setting and hardening process and from moisture changes in the cement-water paste [18].

The properties of concretes resulting from the use of particular aggregates depends upon: - 1) The mineral character of the aggregate particles, particularly as related to strength, elasticity, and durability; 2) The surface characteristics of the particles, particularly as related to the workability, density, and economy of the mix; and 3) The amount of aggregate in unit volume of concrete, particularly as related to cost and to volume changes due to drying [23].

Aggregate particles that have an angular shape or a rough texture, such as crushed stone, give greater strength for a given free water/cement ratio but need more water than smooth and rounded particles to produce concrete of the same consistence. With smaller sized aggregates, the amount of sand needed to fill the voids increases in water demand. To maintain the free water/cement ratio necessary for strength and durability, at the specified consistence, more cement and /or admixture is necessary [13].

The sand and coarse aggregates need to be proportioned to produce a stable and cohesive mix at the required consistence with the minimum amount of water. Badly proportioned constituents require an excessive amount of water to achieve the required slump and this will result in concrete of lower strength and durability, as well as resulting in a mix prone to segregation.

2.5. Properties of Aggregates

To know more about the concrete it is very essential that one should know more about the aggregates that constitute major volume in concrete. Cement is the only factory made standard component in concrete. Other ingredients, namely, water and aggregates are natural materials and can vary to any extent in many of their properties [19].

The physical properties like specific gravity, porosity, thermal, and the chemical properties of an aggregate are attributed to the parent rock. However, the shape and surface texture of natural aggregates and the density, porosity, in addition to shape and surface texture in artificial aggregates are attributed from the mode of production. It is, therefore, very important to give a due consideration to the source and mode of production of aggregates.

2.6. Classification of Aggregates

Aggregates are generally classified based on their source, their chemical composition, their weight, their size or the mode of preparation. However, the method of classification widely used in concrete works is based on aggregate size. Aggregates bigger than 4.75 mm in diameter are classified as coarse aggregates and those smaller than 4.75 mm are classified as fine aggregates. In some countries all-in aggregate, an aggregate composed of both fine and coarse aggregate is made available in the market [18].

2.6.1. Mineralogy and Petrography

Rocks are naturally occurring crystalline, cemented or consolidated materials that form the immediate crust. They are subdivided into types according to mineralogical, petrological and physical characteristics [22]. Almost all natural aggregate materials originate from bed rocks.

There are three kinds of rocks, namely, igneous, sedimentary and metamorphic [19].

a. Aggregates from Igneous Rocks

Most igneous rocks make highly satisfactory concrete aggregates because they are normally hard, tough and dense. Therefore, bulks of the concrete aggregates, that are derived, are of igneous origin [19].

The most widespread of all the igneous rocks are basalts. Basalts are dark colored, fine grained extrusive rocks. The mineral grains are so fine that they are impossible to distinguish with the naked eye or even a magnifying glass. Most basalt is volcanic in origin and was formed by the rapid cooling and hardening of the lava flows. Some basalt is intrusive having cooled inside the Earth's interior.

b. Aggregates from Sedimentary Rocks

The quality of aggregates derived from sedimentary rocks will vary in quality depending upon the cementing material and the pressure under which these are originally compressed. Some siliceous sand stones have proved to be good concrete aggregate. Similarly, the limestone also can yield good concrete aggregate [19].

The thickness of the stratification of sedimentary rock may vary from a fraction of a centimeter to many centimeters. If the stratification thickness of the parent rock is less it is likely to show up even in an individual aggregate and thereby it may impair the strength of the aggregate. Such rocks may also yield flaky aggregates. The degree of consolidation, the type of cementation, the thickness of layers and contamination, are all important factors in determining the suitability of sedimentary rock for concrete aggregates [19].

c. Aggregates from Metamorphic Rocks

Many metamorphic rocks particularly quartzite and gneiss have been used for production of good concrete aggregates [19].

Classification of rocks according to their mode of formation is summarized in Table 2.1.

Table 2.1 Classification of Rocks According to their Mode of Formation [19]

Igneous	**Sedimentary**	**Metamorphic**
Formed from the solidification of molten rock 1. Volcanic - Basalt - Trachyte 2. Plutonic - Granite	Formed as strata as a result of sedimentation from the disintegration products derived from rocks. - Sand stone - Lime stone - Shale	Either igneous or sedimentary that has been altered structurally and mineralogical by heat or pressure or both acting together.
They are very good concrete making materials.	If hard, sand stone and lime are good materials for	They are of minor interest for building purposes except marble.

It was found in some literature that the type of rock normally used for concrete production in Ethiopia is igneous rock. Especially, basalt and rhyolites are widely used. In addition to igneous rocks, sedimentary rocks such as black lime stones are also used for concrete production [17].

2.6.2. Chemical Composition

There are three main classes of aggregates differing in their chemical composition and these are derived from argillaceous, siliceous or calcareous rocks as it is shown in Table 2.2

Table 2.2 Classification of rocks according to their chemical composition [18]

Argillaceous	**Siliceous**	**Calcareous**
Composed primarily of aluminum (Al_2O_3) the chief component of clay	Composed primarily of silicon dioxide (SiO_2), the principal ingredient of quartz sand	Composed primarily of calcium carbonate or lime ($CaCO_3$)

Hence, the physical properties of concrete are dependent on the corresponding properties of the aggregates. Civil engineers are more concerned with the physical, rather than the chemical or mineralogical, properties of aggregates.

2.6.3. Weight

Based on their weight aggregates are divided into three groups:-1) Heavy aggregates with specific gravity more than 4.0 2) Normal weight aggregates with specific gravity between 2.4 and 3.0 and 3) Light weight aggregates such as pumice and scoria which are used to make light weight concrete. [6].

Lightweight aggregates

All lightweight materials are relatively weak because of their high porosity, which gives them reduced weight. This imposes a limitation on strength. Lightweight aggregates are used to reduce weight in structural elements or to give improved thermal insulation [13].

Mikyas (1970) investigated the concrete making properties of lightweight aggregate using concrete made with Ethiopian pumice and scoria. Satisfactory structural capacity was obtained in addition to reduction of imposed dead loads on structures [18]. Use of local lightweight and cheaper Ethiopian aggregate (scoria) as a replacement to crushed rocks had been studied by Girma (1982). The structural properties of lightweight aggregates, which were used with varying proportions to normal weight, were found to be structurally sound [14].

Pumice

Pumice is a very light, porous igneous rock that is formed during volcanic eruptions. It is made up of very tiny crystals, since they cool so quickly above ground. The texture of pumice is rough and has many hollows and cavities. In fact, it forms from frothy lava that has lots of gas bubbles trapped in it, and all those little holes used to have gas trapped in them. It has bulk density of 500 to 900 kg/m^3. The varieties of pumice, which are not too weak structurally, make a satisfactory concrete with a density of 700 to 1400 kg/m3 and with good insulating characteristics, but high absorption and high shrinkage.

Scoria

Scoria rocks are igneous rocks that are found when lava cooled quickly above ground. One can see where little pockets of air had been. Scoria is actually a kind of glass and not a mixture of minerals. It is abundantly found in Addis Ababa and along the rift valley, on occasions newly formed scoria is observed along sides of the road to Metahara.

2.6.4. Source

As regards the source, aggregates may be natural or artificial. Natural aggregates are obtained from river beds (sand, gravel) or from quarries (crushed rock) while artificial aggregates are generally obtained from industrial wastes such as the blast furnace slag [18]. Classes of aggregates with respect to their source are shown in Table 2.3. Almost all aggregates used for construction is natural in origin. In addition to natural gravels and crushed rock, a number of manufactured aggregates are available for use in concrete [13].

Table 2.3 .Aggregate Classification with Respect to their Source

Natural	Artificial
Sand, Gravel, Crushed Rock such as Granite, Quartzite, Basalt, Sandstone	Broken Brick, Air cooled slag

In most parts of Ethiopia sand is obtained from river beds while coarse aggregate is prepared from crushed rock and sold as crushed stone aggregate. The majority of aggregate sources in Addis Ababa are located around rivers within the city. The big river banks of Akaki River and Matahara River (around Bole Airport) are the main sources for the production of coarse aggregate in Addis Ababa.

2.6.5. Particle Shape and Texture

Further, aggregates may be classified on visual inspection in terms of particle shape and texture (BS. 812:1954), as is shown in Table 2.4.

Table.2.4. Shape and Texture of Aggregates [22]

Characteristic	Classification	Description	Examples
Particle shape	Angular	Well-defined edges at the intersection of rough faces, and three dimensions nearly equal.	Crushed rocks of all types; rubble; crushed slag.
	Elongated	Particles, usually angular, having a Length/width ratio greater than 3.	-
	Flat or flaky	Particles having a width/thickness ratio greater than 3.	-
	Flat and elongated	Particles having width/thickness and Length/width ratios greater than 3.	Crushed or laminated rock.
	Irregular	Naturally irregular or partly shaped by attrition, having rounded edges and three dimensions nearly equal.	Pit gravel, land or dug flint.
	Rounded	Fully water-worm or shaped by attrition, and three dimensions nearly equal.	River or seashore gravel; desert, seashore and wind-blown sand.
Surface texture	Crystalline	Easily visible crystalline constituents.	Granite, gabbro, gneiss
	Granular	Fracture showing more or less uniform rounded grains.	Sandstone
	Rough	Rough fracture of fine-grained or medium-grained rock with no easily visible crystalline constituents.	Basalt, felsite, porphyry, Carboniferous limestone.
	Smooth	Water-worn or smooth due to fracture of laminated or fine-grained rock.	-

2.7. Aggregate Type Selection

As aggregates form the bulk of the volume of concrete and can affect its performance, the selection of a suitable material is important [13]. Many properties of aggregates depend mostly on the quality of parent rock. However, there are some properties possessed by the aggregates which are important so far as concrete production is concerned. These properties have no relation with the parent rock, particularly the shape and size. In addition, selection of aggregates is required to be done judiciously taking the economic factor into consideration.

The aggregate that can be delivered to the mixing plant directly may not be the most economical one. It may require cement content more than that of another source. Also very often, the cost of some processing accomplishes the reduction in cement content of the concrete. In general, the aggregate that brings about the desired quality in the concrete with least over all expense, should be selected [19].

2.8. Determination of Aggregate Requirement

For the calculation of batch quantities, for making mix adjustments, for computing effective water - cement ratios and yields, and for making estimates of quantities required for jobs, some of or all of the information like specific gravity of aggregate particles, unit weight of aggregate in bulk, free moisture and absorption and gradation of aggregate are needed.

Methods that have been used or are used to choose the relative proportions of the various sizes are as follows [23].

1. Trial mix of the concrete to obtain maximum economy with good workability
2. Empirical criteria based upon
a. Unit weight or void content
b. Sieve analysis and grading diagrams
3. Trial mixtures of dry aggregates to obtain maximum density
4. Rule- of - thumb ratios

The first method is probably the most satisfactory in the long run, since the final criterion of optimum proportions is a concrete which most nearly possesses the necessary economy and workability. However, with more than two sizes of aggregate the number of trials may become large, so that familiarity with the significance of unit weights and gradations method.

2) Serves as an excellent guide to the most desirable combinations. The third method may also serve as a guide, except that, as has been pointed out, maximum density of dry aggregates doesn't give optimum workability in a concrete mixture, so that either trial mixes or empirical modification of proportions is still necessary [23]. However, there is no standard procedure in Ethiopia for concrete mix design. Due to this reason concrete producers in Ethiopia are obliged to use mix design procedures developed for other countries.

2.9. Properties of Concrete making Aggregates

As much as the aggregate occupies 65 to 75 percent of the volume of concrete the importance of having information on the physical and chemical characteristics cannot be over emphasized.

2.9.1. Specific Gravity

The specific gravity of a substance is the ratio of the unit weight of the substance to the unit weight of water. Applied to aggregates, the term specific gravity customarily refers to the density of the individual particles, not to the aggregated mass as a whole [23].

In connection with concrete mix calculations, it is desired to know the spaces occupied by the aggregate particles with in the relatively thick cement paste regardless of whether or not pores or internal voids exist within the particles. Hence, there is determined what is called *the bulk specific gravity* of the particles. The bulk specific gravity is defined as the ratio of the weight in air of a given volume of a material at the standard temperature to the weight in air of equal volume of distilled water at the standard temperature. For use in the computation of concrete mixes the bulk specific gravity is always determined for saturated surface dry aggregates. The specific gravities of a number of commonly used aggregates fall within the range of 2.6 to 2.7 although there are satisfactory materials for which the specific gravity falls outside this range [23].

2.9.2. Unit Weights and Voids

Unit weight is the weight of a unit volume of aggregate, usually stated in kg per cubic meter.

In estimating quantities of materials, and in mix computations when batching is done on a volumetric basis, it is necessary to know the conditions under which the aggregate volume is to be measured: (1) loose or compact, and (2) dry, damp, or inundated [23]. The general range in unit weights of some fine and coarse aggregates are shown in Table 2.5.

Table 2.5 General Range in Unit Weight of Some Natural Aggregates [23]

Material	**Kg/m3**
Sand (dry)	1520 – 1680
Gravel	1280 – 1440
Crushed Stone	1250 – 1400

Bulk density measures the weight of the aggregate that fills a container of unit volume part of which is void because of loose packing of the particles. The bulk density is used to convert quantities by weight to quantities by volume for batching concrete. In general, for comparison of different aggregates and calculation of mix quantities the standard conditions are dry and compact (rodded). However, for scheduling volumetric batch quantities, the unit weight in the loose, damp state should also be known [19].

2.9.3. Surface Moisture, Porosity and Absorption

As regards moisture content, the various states in which an aggregate may exist are: - 1) Oven dry 2) Air dry 3) Saturated surface dry and 4) Damp, or wet. [23]

In proportioning the materials for concrete, it is always taken for granted that the aggregates are saturated and surface dry [19].

It should be noted that if the aggregates are dry they absorb water from the mixing water and there by affect the workability and, on the other hand, if the aggregates contain surface moisture they contribute extra water to the mix and thereby increase the water/cement ratio.

Both these conditions are harmful for the quality of concrete. In making quality concrete, it is very essential that corrective measures should be taken both for absorption and free moisture so that the water/cement ratio is kept as exactly as per the design [19]. Therefore, in calculating or measuring quantities for concrete mix it is important to know the state at which the aggregate is used [18].

Absorption represents the total water contained in the aggregate in the saturated surface-dry condition and the surface moisture (or free moisture) is the water in excess at the saturated surface-dry state. The total water content of a damp or moist aggregate is equal to the sum of absorption and surface moisture content. The surface or free moisture content is generally given in terms of percent of the weight of the saturated surface dry aggregates [18]. The absorption capacity is a measure of the porosity of an aggregate.

Approximate values of the absorption capacities of some types of aggregates are given in Table 2.6.

Table 2.6 Approximate absorption capacities of some types of stones used for aggregate [18]

Material	Absorption Capacity % By Wt.
Sand	0.0 – 2.0
Gravel	0.5 – 1.0
Basalt	0.0 – 0.50
Granite	0.0 – 0.50
Limestone (firm)	0.5 – 1.0
Sand stone	2.0 – 7.0
Trap rock	0.0 – 0.50

Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete. The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids [19].

The porosity of aggregate is important since it affects its bulk specific gravity, permeability and absorption which in turn affect the properties of the resulting concrete. Unless their openings are very wide, the surface pores are considered impermeable to cement paste because of its viscosity. Hence, the gross volume of the aggregates particle, including the surface pores of narrow opening, is considered to be solid for the purpose of calculating the aggregate content in concrete [18].

Determination of moisture content in aggregate is of vital importance in the control of the quality of concrete particularly with respect to workability and strength. The measurement of the moisture content of aggregate in the field must be quick, reasonably accurate and must require only simple apparatus which can easily be handled and used in the field. Some of the methods that are being used for determination of moisture content of aggregate are:-i) Drying method ii) Displacement method iii) Calcium Carbide method and iv) Measurement by electrical meter [19]

2.9.4. Gradation

In order to calculate the proportions of the different ingredients and produce concrete of desired proportions, it is important and indeed required to determine the characteristics of the aggregate which include among other things its gradation. The grading of particle size distribution of aggregate is usually determined by a sieve analysis [18].

A sample of aggregate for sieve analysis is first surface dried and then sieved through the series, starting with the largest. The standard sieve sizes used by some internationally accepted standards are given in Table 2.7. The weight retained on each sieve is recorded and the percentage computed. The summation of the cumulative percentage of the material retained on the sieves (not including the intermediate sieves) divided by 100 is called the *fineness modulus.* It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of grading which will produce a given fineness modulus [18]. The following limits may be taken as guidance.

Fine sand:	**F.M =2.2-2.6**
Medium Sand:	F.M =2.6- 2.9
Coarse Sand:	F.M =2.9-3.2

Sand having a fineness modulus more than 3.2 will be unsuitable for making satisfactory concrete [19]. According to literature, for concrete work, the fineness modulus of sand should lie between 2.6 and 3.1[23].

Table 2.7 Standard Sieves and Square Openings [18].

For Fine Aggregates			For Coarse Aggregates		
ES Series	**ASTM Series**		**ES Series**	**ASTM Series**	
Sieve Size & Clear Opening	Sieve Size	Clear Opening	Sieve Size & Clear Opening	Sieve Size	Clear Opening
9.5mm	3/8 in	0.375 in	75 mm	3 in	3.00 in
4.75mm	No 4	0.187 in	63 mm	(2 in)*	2.00 in
2.36mm	No 8	0.0937 in	37.5 mm	1½ in	1.50 in
-	-	-	-	1 in	1.00 in
1.18mm	No. 16	0.0469 in	19 mm	¾ in	0.75 in
600µm	No. 30	0.0232 in	13.2 mm	(½ in)*	0.50 in
300µm	No.50	0.0117 in	9.5 mm	3/8 in	0.375 in
150µm	No.100	0.0059 in	4.75 mm	No 4	0.187 in

* These values called "intermediate" or "full size sieves" are not included in the series for fineness modulus calculations.

Aggregate is graded so as to have different sizes of particles, from the required largest size to the very fine. The use of well - graded mixture of aggregates results in improved workability of the concrete and economy of the cement since such aggregates have a decreased amount of voids between their particles and they consequently require less cement paste[18].

It is reported that, for mixes of given consistence and cement content, a well-graded aggregate produces a stronger concrete than a poorly graded one because less water is required to give suitable workability. In addition, with a given cross sectional dimension of a concrete structural member and spacing of reinforcements, it is in general recommended to select the maximum possible size of aggregate.

The maximum size and the grading are important because they affect:-1) the relative volume occupied by the aggregate, hence the economy in producing concrete 2) The surface area of the aggregate which determines the amount of water necessary to wet all the solids, 3) The workability of the mixture, 4) The tendency to segregation, and 5) The porosity and shrinkage.

This implies that from the point of view of selecting proportions (mix design), it is important to have well graded coarse and fine aggregate with maximum possible size [21].

A suitable gradation of the combined aggregate in a concrete mix is desirable in order to secure workability and to secure economy in the use of cement [23].A sample of the well graded aggregate containing minimum voids will require minimum paste to fill up the voids in aggregates. Minimum paste will mean less quantity of cement and less quantity of water, which will further mean increased economy, higher strength, lower -shrinkage and greater durability [19].

For the reason that both the maximum size and grading are important factors to be considered when calculating proportions for concrete mix, national standards specify grading limits for coarse and fine aggregates. According to the Ethiopian Standard ES. C. D3. 201 fine aggregate should consist of natural sand obtained from the natural disintegration of rocks or sand obtained from crushed stones whereas coarse aggregate should be gravel, crushed gravel, or crushed stone. In addition, according to the same standard, the fine aggregate should not have more than 45 percent retained between any two consecutive sieves and the fineness modulus should not be less than 2.0 or more than 3.5 with a tolerance of ± 0.2 [7].

The grading or particle size distribution of fine aggregate and coarse aggregate should be within limits specified in Table 2.8 and Table 2.9 respectively. Standards such as B.S.882:1954 prescribe grading requirements combined or all-in aggregate. These are given in Table 2.10.

Table 2.8 Grading Requirement for Fine Aggregate [7]

Sieve size (ES)	ASTM Designation	Percentage Passing
9.5 mm	3/8	100
4.75 mm	-	95- 100
2.36 mm	No. 8	80- 100
1.18 mm	No. 16	50- 85
600 µm	No. 30	25- 60
300 µm	No. 50	10- 30
150 µm	No. 100	2 - 10

Table 2.9 Grading Requirement for Coarse Aggregate **[7]**

Sieve Size(ES)	ASTM Designation	Percentage Passing		
		Nominal Size of Graded Aggregate (mm)		
		38* - 5	19*- 5	13*- 5
75 mm	3 in	100		
63 mm	(2 in)	-		

37.5 mm	11/2 in	95 - 100	100	
19 mm	¾ in	30 – 70	95 – 100	100
13.2 mm	½ in	-	-	90-100
9.5 mm	3/8 in	10 - 35	25 – 55	40 – 85
4.75 mm	No. 4 0	0–5	0 – 10	0 - 10

Table 2.10 Grading Requirements for All- In Aggregate (B.S. 882:1954) [7]

Percentage by Weight Passing B.S. Sieves		
	1 ½ in (37 mm)	¾ in (19 mm)
B. S. Sieve Size	Nominal Size	Nominal Size
3 in (75 mm)	100	-
1 ½ in (37.5 mm)	95 - 100	100
¾ in (19 mm)	45 - 75	95 - 100
3/16 in (4.75 mm)	25 - 45	30 - 50
25 mm	8 - 30	10 - 35
100 (4.75 mm)	0 – 6	0 – 6

*The maximum size of an aggregate is defined by the largest sieve through which at least 90% of the aggregates passes.

Divided aggregate is preferable to all - in aggregate for consistent grading and the practical control of quality in concrete manufacture. The various sizes of particles of which an aggregate is composed should be uniformly distributed [22]. Generally, divided aggregate is used in the Ethiopian construction industry.

Standard Grading Curve

When a sieve analysis has been completed, the weight of aggregate retained on each sieve is expressed as a percentage of the total weight of the sample.[20] The results obtained as percent passing or percent retained coarser can be shown graphically in aggregate grading charts. On the horizontal axis are read the sieve openings with arithmetic or logarithmic scale.

They are arranged with increasing sieve opening sizes form left to right. On the vertical scale on the left side of the chart are indicated the total percentage coarser, 0 to 100, form bottom to top. The corresponding values for the percentage passing are read on the right side of the chart [18]. However, it is also possible to draw the chart the other way round.

A grading chart is especially useful in checking whether the results obtained from the sieve analysis of a given sample fall within the limits specified by standards. If, however, they fall outside the limits adjustments must be made. In fact in some places it is difficult to obtain well graded aggregates especially sands. In this case the combined aggregate may be based on what is called gap grading meaning certain sizes are missing. This often happens in places where the coarse aggregate is crushed stone and where only very fine sand is available.

The grading of fine aggregates has much greater effect on workability of concrete than does the grading of coarse aggregate. Experience has shown that usually very coarse sand or very fine sand is unsatisfactory for concrete making. The coarse sand results in harshness, bleeding and segregation, and the fine sand requires a comparatively greater amount of water to produce the necessary fluidity [19].

It is easiest to maintain the uniformity of concrete if the quantities of concrete are to be handled is very large, it may be advantageous to blend several fractions of coarse aggregate to maintain uniform grading. This is a common procedure in ready-mixed concrete plants, due to the reason that concrete can be produced more economically when corrections for grading variability are eliminated [20].

Maximum Size of Aggregates

The maximum size of an aggregate is determined from its sieve analysis and is generally designated by the largest sieve through which at least 90% of the aggregates pass. The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Using the largest possible maximum possible size will result in: - i) reduction of the cement content ii) reduction in the water requirement iii) reduction of drying shrinkage.

The bigger the size of the aggregate, the less is the surface area and hence less amount of water is required for wetting the surface and less matrix or paste is required for lubricating the surface to reduce internal friction. For a given quantity of water and paste a bigger size of aggregate will give higher workability [19].

The maximum size of coarse aggregate is governed by the type of work to be done. For reinforced concrete it should be such that the concrete can be placed without difficulty, surrounding all reinforcement thoroughly, particularly in the cover zone, and filling the corners of the formwork.

The use of a larger aggregate results in a slightly reduced water demand and hence a slightly reduced cement content for a given strength and workability [13].

Smaller aggregate, usually 10mm maximum size, may be needed for concrete that is to be placed through congested reinforcement for example. In this case the cement content may have to be increased by 10 - 20 % to achieve the same strength and workability as with a 20 mm maximum-sized aggregate concrete because the sand content and water content normally have to be increased to produce a cohesive mix [13].

2.9.5. Physical Properties

With respect to physical properties, coarse aggregates should comply with the following characteristics [22]:- i) Abrasion-resistance ii) Aggregate crushing value iii) Aggregate impact value

2.9.6. Shape

The shape of aggregate is an important characteristic since it affects the workability of concrete. The shape of the aggregate is very much influenced by the type of crusher and the reduction ratio, ѵ, i.e., the ratio of the size of material fed into crusher to the size of the finished product [19]. Particle shape and size distribution influence the water content necessary to obtain a mix of suitable resistance, and then by affecting the compressive strength, drying shrinkage and durability of the resulting concrete. In addition, the sum of the flakiness and elongation indices should not exceed 40% or 35% in some standards [22].

Description and examples of different classes of shapes of aggregates are given in Table 2.11.

Particle shape of aggregates can be calculated by one of the following methods:-i) Thickness and length gauges ii) Proportion Calliper iii) Angularity number

From the standpoint of economy in cement requirements for a given water/cement ratio, rounded aggregates are preferable to angular aggregates. On the other hand, the additional cement required for angular aggregate is offset to some extent by the higher strength and sometimes by greater durability as a result of the inter- locking texture of the hardened concrete and higher bond characteristic between aggregate and cement paste [19].

Table 2.11 Shape of Particles [19]

Classification	Description	Examples
Rounded	Fully watered worn or completely shaped by attrition	River or seashore gravels; desert, seashore and wind-blown sands
Irregular or partly rounded	Naturally irregular, or partly shaped by attrition, having rounded edges	Pit sands and gravels; land or dug flints; cuboid rock
Angular	Possessing well-defined edges formed at the intersection or roughly planar faces	Crushed rocks of all types; talus; screes
Flaky	Material usually angular, of which the thickness is small relative to the width and/or length	Laminated rocks

2.9.7. Texture

Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it. It has been also shown by experiments that rough textured aggregate develops higher bond strength in tension than smooth textured aggregate [19]. The summary of these experiments is shown in Table 2.12.

Table 2.12 Influence of Texture on Strength [19]

Percent of particles		Water/ Cement Ratio	Strength, 28 days Kg/cm2	
Smooth	Rough		Flexural	Compressive
100	**0**	**0.54**	**43**	**348**
50	**50**	**0.57**	**46**	**321**
0	**100**	**0.60**	**48**	**295**

2.9.8. Strength

When cement paste of good quality is provided and its bond with the aggregate is satisfactory, then the mechanical properties of the rock or aggregate will influence the strength of the concrete. Therefore, it can be concluded that while strong aggregates cannot make strong concrete, for making strong concrete, strong aggregates are essential requirement [19].

Assessment of strength of the aggregate is made by using a sample of bulk aggregate in a standardized manner. This test is known as aggregate *crushing value test*. Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load [19].

2.9.9. Aggregate Impact Value

Apart from testing aggregate with respect to its Crushing Value and impact resistance, testing the aggregate with respect to its resistance to wear is an important test for aggregate to be used for road constructions, ware house floors and pavement constructions. Specified abrasion change and abrasion and crushing value percentage limits are given in Table 2.13 and Table 2.14 respectively. Three tests are in common use to test aggregates for its abrasion resistance:-i) Deval attrition test ii) Dorry abrasion test iii) Los Angeles test

Table 2.13 Specified Abrasive Change [19].

Grading	Number of spheres	Weight of change (gm.)
A	12	5000±25
B	11	4585±25
C	8	3330±20
D	6	2500±15

Table 2.14 Abrasions and Crushing Value Percentage Limits [22]

Aggregate Type	Los Angeles Value	Aggregate Crushing Value
Hornfels	25	20
Andesite; Basalt	30	25
Breccia; Dolerite	30	25
Micro diorite; Micro granite	30	25
Microsynite; Rhyolite	30	25
Limestone; Quartzite	35	30
River Gravel; Slate	35	30
Granite; Quartz	45	40

The average values of different tests on Rocks of different groups are summarized in Table 2.15.

Table 2.15 Average Test Values for Rocks of Different Groups [19].

Rock Group	Crushing Strength(Kg/cm2)	Aggregate Crushing Value (%)	Abrasion value	Impact value	Attrition Value		Specific gravity
					Dry	Wet	
Basalt	2070	12	17.6	16	3.3	5.5	2.85
Flint	2143	17	19.2	17	3.1	2.5	2.55
Gabbro	2036	-	18.7	19	2.5	3.2	2.95
Granite	1929	20	18.7	13	2.9	3.2	2.69
Gritstone	2286	12	18.1	15	3.0	5.3	2.67
Hornfels	3536	11	18.8	17	2.7	3.8	2.88
Limestone	1714	24	16.5	9	4.3	7.8	2.69
Porphyry	2393	12	19	20	2.6	2.6	2.66
Quartzite	3391	16	18.9	16	2.5	3.0	2.62
Schist	2536	-	18.7	13	3.7	4.3	2.76

2.9.10. Modulus of Elasticity

Modulus of elasticity of aggregate depends on its composition texture and structure. The modulus of elasticity of aggregate will influence the properties of concrete with respect to shrinkage and elastic behavior and to very small extent creep of concrete [19].

2.10. Durability of Aggregates

Since aggregates make up the bulk of concrete, any lack of durability of the aggregate will have disastrous consequences for the concrete. If there are durability problems, special screening tests may be required, routinely to avoid problem aggregates, or special measures must be taken to counter act the effects of undesirable aggregates. The latter approach will become more important in the future as deposits of high-quality aggregates are worked out and more marginal material is brought into use [20].

Aggregates should be hard and should not contain materials that are likely to decompose or change in volume when exposed to weather. Examples of undesirable materials are lignite, coal, pyrite and lumps of clay.

2.10.1. Chemical Reactions

For a long time aggregates have been considered as inert materials but later on, particularly, after 1940's it was clearly brought out that aggregates are not fully inert. Some of the aggregates contain reactive silica, which reacts with alkalis present in cement i.e. sodium oxide and potassium oxide. The formation of the products of the reaction between the alkalis and the aggregate causes abnormal expansion, which, however, sometimes doesn't take place until two or more years after the concrete has been placed [23].

The types of rocks which contain reactive constituents include traps, andesite, rhyolites, siliceous limestone and certain types of sandstones. The reactive constituents may be in the form of opals, cherts, chalcedony, volcanic glass, zeolites etc. The reaction starts with attack on the reactive siliceous minerals in the aggregate by the alkaline hydroxide derived from the alkalis in cement. As a result, the alkali silicate gels of unlimited swelling type are formed.

When these conditions are congential, progressive manifestation by swelling takes place, which results in disruption of concrete with the spreading of pattern cracks and eventual failure of concrete structures. The rate of deterioration may be slow or fast depending up on the conditions [19].

The following are factors which promote the alkali - aggregate reaction:-i) Reactive type of aggregate ii) High alkali content in cement iii) Availability of moisture iv) Optimum temperature conditions

Many specifications restrict the alkali content to be less than 0.6 percent expressed as soda equivalent. A cement meeting this specification is designated as low alkali cement. Field experience has never detected serious deterioration of concrete through the process of alkalis less than 0.6 percent. In exceptional cases, however, cements even with lower alkali content have caused objectionable expansion [19].

Evaluation of aggregates for potential damage due to alkali- aggregate reaction requires judgment based past service record of the aggregate source, if available, and possible use of one or more laboratory procedures such as C295 for petrographic examination, C227 for mortar bar expansion of the aggregate used with cement, and the quick chemical method C289. In some cases, one or more of the tests will indicate potential reactivity, but if the source has good service record for a long period of time in a similar environment, and if the aggregate in such concrete is petro graphically similar to the aggregate under evaluation, it may be acceptable for use, particularly with a low –alkali cement.

Use of certain pozzolans, blended cements, or slag cement may be sufficient to eliminate the risk of deleterious alkali-aggregate reaction and may be determined by ASTM C441 [15]. One material testing laboratory in Addis Ababa has all the laboratory equipments necessary to carry out all the three test methods mentioned above. However, it is complained that the number of test samples submitted for assessment of potential alkalis aggregate reaction is too small.

2.10.2. Soundness

Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. These physical conditions are the freezing and thawing, variation in temperature, alternate wetting and drying in salt water. Aggregates which undergo more than the specified amount of volume change are said to be unsound aggregates [19]. The disintegrative resistance to an aggregate to sulphate solution is a means of estimating its soundness to weathering action, particularly where relevant service records are inadequate or unavailable [22].

2.10.3. Deleterious Substances/Cleanliness

The concrete aggregate should be free from impurities and deleterious substances that are likely to interfere with the process of hydration and results in prevention of effective bond between the aggregate and matrix. These impurities sometimes reduce the durability of the aggregate. Generally, the fine aggregate obtained from natural sources is likely to contain organic impurities in the form of silt and clay. The manufactured fine aggregate doesn't normally contain organic materials. But it may contain excess of fine crushed stone dust.

Coarse aggregate stacked in the open and unused for long time may contain moss and mud in the lower level of the stack [19]. Limits of deleterious substances in concrete aggregates are given in Table 2.16.

Sometimes excessive silt and clay contained in the fine or coarse aggregates may result in increased shrinkage or increased permeability in addition to poor bond characteristics. The excessive silt and clay also necessitates greater water requirements for given workability. The quantity of clay, fine, silt and fine dust are determined by sedimentation method. To ascertain whether a sample of fine aggregate contains permissible quantity of organic impurities or not, a simple test known as colorimetric test is made [19].

Table 2.16 Limits of Deleterious Materials [19].

Deleterious Substance	**Fine Aggregate**		**Coarse Aggregate**	
	Uncrushed	**Crushed**	**Uncrushed**	**Crushed**
Clay and Lignite	1.00	1.00	1.00	1.00
Clay Lumps	1.00	1.00	1.00	1.00
Soft fragments	-	-	3.00	-
Material passing 75 micron				
IS sieve	3.00	3.00	3.00	1.00
Shale	1.00	-	-	-

Note: The sum of the percentage of all deleterious material shall not exceed five.

Aggregates should be clean and free from organic impurities: aggregate containing organic material makes poor concrete. The particles should also be free from coatings of dust of clay, as these prevent the proper bonding of the material. An excessive amount of fine dust or stone 'flour' may prevent the particles of stone from being properly coated with cement and thus lower the strength of the concrete [13].

Gravels and sand are sometimes washed by the suppliers to remove excess fine (clay and silt, for example) and other impurities, which, if present in excessive amounts, result in a poor quality concrete. However, excessive washing can remove all fine material passing the 300µm sieve. This may result in a concrete mix lacking in cohesion and, in particular, being unsuitable for placing by pump. Sand deficient in fines also tends to increase the bleeding characteristics of the concrete, which can result in poor vertical finishes due to water scour [13].

2.11. Thermal Properties

Rock and aggregate possess three thermal properties which are significant in establishing the quality of aggregate for concrete construction. They are [19] :-i) Coefficient of expansion

ii) Specific heat iii) Thermal conductivity

Out of the three, specific heat and conductivity are found to be important only in mass concrete construction where rigorous control of temperature is necessary. Also these properties are of consequence in case of light weight concrete used for insulation purpose.

When dealing with the aggregate in general it will be sufficient to deal with only the coefficient of expansion of the aggregate, since it interacts with the coefficient of thermal expansion of cement paste in the body of the set-concrete [19].

2.12. Aggregate Beneficiation

If an aggregate doesn't meet the specifications required for the job, the concrete producer is faced with two courses of action. One option is to reject the aggregate or the other is to consider taking measures to bring the aggregate up to specifications. Beneficiation of aggregate may be the only available solution if aggregate supplies are scarce, but it will add to cost of the aggregate and hence of the concrete [20].

Chapter Three: - Methodology

3.1. Source and Collection of Data

- Literature review
- Survey a selected aggregate production quarry site (Bole Bulbula) of Addis Ababa City Roads Authority. The survey incudes observation, on site data collection and conducting interviews. The relevant conditions of aggregate, which majority of them occur naturally, are subjected to a wide range of variability and quality problems under each topic discussed.
- Carry out Case study for relevant materials:-e.g. Reference books, published journals, use of internet web sites to find relevant information.
- Collecting results of tests from laboratory for the selected quarry site.
- Collecting relevant data from governmental institutions and large construction materials Suppliers in Addis Ababa.

3.2. Processing of Data

- Simple analysis of test results from observed and secondary data used in laboratory.
- In analysis the case study that the reason why aggregate making materials fail to comply with requirements attributes to the handling of the materials in the construction industry with respect to quality, quantity and production process materials satisfying requirements in construction projects. Finally, a recommendation on mitigation measures not to encounter for such defect works is addressed.
- Evaluate the Material

When evaluating the material these points were considered:

  - Is the material reflects recent/current information?
  - What is the relationship of this work to other material we have read on the same topic, does it substantiate it or add a different perspective?

- Analysis the Findings

In analysis the materials and the case study together we considered:

  - What conclusions can be drawn?

- Draw Conclusion and Recommendation

Chapter Four:-Results and Discussion

4.1. Results

4.1.1 Tests on Aggregates

Testing is the means by which the properties of a material are routinely evaluated and compared with the appropriate specification requirements. This coarse aggregate type of material is that used in concrete and pavements of asphalt concrete that is used in may well lead to different specification requirements. Hence, in my real case that Addis Ababa City Road Authority (AACRA) is used aggregate for Public infrastructures extension, Upgrading, rehabilitation and other related works of road construction projects (bridge, drainage structures) and asphalt concrete pavements. Therefore, AACRA laboratory is committed to that test results, which leads to provide a historical records of how the properties of a material vary with time to time due to various reasons.

My paper was also begin with relevant theories, which shows the aspects of handling of aggregate in the literature and an over review discussion deals about my case study that pinpoints on coarse aggregate, fine aggregate and rock samples. Hence, my real case target area was framed within these topics and observed the real practices existed in AACRA or through their laboratory. Moreover, Sieve analysis, absorption and specific gravity as well as Loss of Abrasion (LA) and Fineness Index (FI) tests were carried out for the coarse aggregate samples and for fine Aggregate Sieve analysis and clay content testes are used.

It is true or necessary that above types of tests is worthwhile to determine the engineering properties of aggregate sources when assessing their quality, which gives me the chance to use those materials to their maximum potential.

Therefore, I conducted my case study in observing among AACRA quarry sites, Bole Bulbula, and discussing with laboratory technician of AACRA staff in which the results of my survey would be presented in this chapter.

4.1.1.1 Coarse Aggregates

While collecting the data from AACRA that begin from collecting the laboratory test request form and shows certain sampling and tests used in AACRA such as Sieve analysis, absorption and specific gravity as well as Loss of Abrasion (LA) and Fineness Index (FI) tests. Hence it is also used as form of research and quality control service. Provision that consumed only for own force account projects. However the out sourced road construction projects are handled through external bodies such as those nominated consultants. Therefore, from this form of tests I realized that there are 13 types of test are described for asphalt concrete structures. My interview based case study considered that the procedures followed in AACRA laboratories that include:-

1- Sampling material obtained from source located at quarry and/or stocks.

2-Standards of testing that are obtained from specification of AACRA, ERA, AASHTO and ASTM. Moreover, the classifications of aggregates are categorized in sizes that are “00, 01, 02, and 03’’.

All these coarse aggregates are used for construction that are consumed by activities of making concrete and asphalt concrete. Hence, the source of coarse aggregate are obtained from stocks and/or from different quarry areas which is located in different locations that are approved by the Engineer and/or material Engineer, including laboratory technicians.

Finally my questioners based survey indicated that, coarse aggregate sampling and testing procedures in AACRA are examined through standardized methods of handling, storage, protection, and loss or waste.

The Observed and Discussed issues witnessed that as they do and/or do not that:-

1.0. Handling:-

1.1. Check: - grade, quantity, and quality.

1.2. Do not deliver by high-sided truck.

1.3. Do not transfer by grab, mechanical shovel or power-assisted equipment on weigh batcher

1.4. Do not Transport by bucket, hopper, dumper and barrow.

2.0. Storage:-

2.1. In prepared bays adjacent to mixer.

2.2. Not in selected grading and particular size.

2.3. On concrete base laid to falls.

3.0. Protection:-

3.1. Cover against frost, snow or rain

3.2. Do not avoid contamination with mud, clay or oil

3.3. Do not install steam heating to base of mound

3.4. Do not check calibrations on weighting equipment

4.0. Loss or Waste

4.1. Do not considered that indiscriminate handling but consumed loss or waste as backfill and sub-base materials

4.2. Contamination of any kind

4.3. Underestimated that failure to trim stocks

4.4. Using as site dressing or to fills site voids

4.1.1.2. Fine Aggregates

It was observed that the number of fine aggregate samples submitted to the laboratory that considered same as the number of coarse aggregate samples submitted for testing. With the same token the number of fine aggregate samples considered in my survey that exceeds the number of coarse aggregate test samples due to various suppliers brings these fine aggregates that obtained from different sources. Hence, sieve analysis and clay content tests were uniformly carried out for the fine aggregates. This case study is a model as an indication of road construction in capital city of Ethiopia that make our study to be unique and become a sample in opening a room for an improvement through further studies to be conducted by scholars for road construction industry in Ethiopia.

4.1.2 Rock Samples

Unfortunately the rock samples are not tested in Addis Ababa City Road Authority laboratory since it is a mandates of Addis Ababa City Energy & Mining Department and all the requirement data and information are taken from this department. Hence due to time and cost constraints that I am forced to narrow the scope of the case study.

4.1.3. Aggregate Production

Controlling the production process is first priority before beginning the road construction that requires producing aggregate with good quality. It is here that all inputs are measured, evaluated and controlled, so that the product conformity and uniformity can be predicted. However, a uniformity of product appears on the last belt of the crusher plant that doesn’t mean the work is over unless the transportation and handling on sites is considered; the uniformity of the product may also be destroyed at all.

It is unfortunate that the material which is naturally good in terms of quality that might not be up to the standard at all if it is not handled properly afterwards. Whatever good quality the naturally available material has, its final quality after all depends on the extraction method employed.

Hence each and every process used in specification of Addis Ababa City Road Authority crashing plant that involved in the production process of coarse aggregate to influence the final aggregate product and ultimately the concrete and asphalt concretes structures that produced by these aggregates. Especially with the aggregate production, the quality of the aggregate products can be influenced; however the raw material such as the rock may manifest some characteristics which cannot be modified by the production process.

It was observed that in this case study that suppliers of AACRA, aggregate producers don't have the knowledge and they need to have more training if all are parties concerned about the quality of the material they are producing. Otherwise, due to this reason it is sometimes difficult to get an aggregate of acceptable quality in AACRA. In addition, the naturally available good quality resource is being used inefficiently and not optimally. Further, the need for knowledge is increasing as our group introduced its questioners that lesson learned from. Therefore, we can realize that conventional concrete aggregate supplies are becoming depleted especially in the Addis Ababa City areas, and environmental aspects prevent the use of existing sources. Also, the importance of having trained aggregate producers in the Addis Ababa City is good for Ethiopia construction industry that does not mean overemphasized.

The previous test results which were analyzed for AACRA Laboratory has signified that good quality natural fine aggregate is available in many small town located near to Addis Ababa; however, the fine aggregate deposit may not have been laid uniformly, meaning knowingly or unknowingly contaminated with sediments or a potential change in quality and in size is possible. This signifies that the importance of treating fine aggregate before it is employed for concrete production is vital. Therefore, to properly make use of this quality of the raw materials, the production process should be carried out in a planned and knowledgeable way.

4.1.4. Standardization

There is no a standard written procedure as to how to handle aggregates while the production process is going on and also how to handle these materials in construction projects in the utilization of aggregates for concrete production. In addition, the number of requirements stated in the AACRA Standard specification is not sufficient to control the quality of fine and coarse aggregates in the own force account road construction projects. Also there is no standard that the coarse or fine aggregate producers should follow in the production of these aggregates. And these needs to produce or to promulgate a standard guide line to control the production process on the side of the statutory bodies. Interviews and observations made in this case study have shown that except Addis Ababa City Energy & Mining Department that provide quarry sites there is no official body assigned for licensing guideline for sand and aggregate producers in city level especially with respect to the quality of the material produced. Specially, Small & Middle Enterprises (SME) or the potential investors in the area are required to submit proposal of their investment. However, there is no control as to whether the producers follow a quality control procedure in the production process or not. In addition, only paper work is done when renewing their license every year.

4.2. Discussion

4.2.1 Production Processes of Concrete Making Aggregates

4.2.1.1 Fine Aggregate Production

Sand plays a critical role as a concrete aggregate and it deserves special attention when considering the means of process control. Unlike coarse aggregate where various types of crushers can be used to upgrade mineral quality, sand basically relies on the same techniques to address both mineral quality and sizing. These techniques are called particle exclusion. Whichever size the producer decides to eliminate for quality reasons obviously also will affect sizing. Good quality natural sand is available in many areas and may be easy to obtain and process. The sand deposits may not have been laid uniformly, meaning a potential change in quality and size is possible. In some deposits, sand found below the water table differs in fines content and quality from that found above the water table.

4.2.1.2 Production Methods of Coarse Aggregates

With the exception of manufactured aggregates, most materials for aggregate production come from bedrock or unconsolidated deposits. A quarry can be established as a suitable outcropping, or overburden may need to be removed before the rock is exposed. Crushed stone aggregates are produced from many natural deposits including; limestone, granite, trap rock and other durable mineral resources. Production of these materials requires blasting and excavating the broken stone from quarries followed by progressive stages of crushing, screening, washing and blending. The numerous sizes and gradations are determined by their intended use and each complies with the specifications established by governmental agencies or customer's requirements. Production of coarse aggregates from rocks involves different processes including stripping, drilling, blasting, crushing and screening.

4.2.1.2.1 Stripping

At this step, the producer should spell out a detailed stripping for each and every deposit it mines. This phase is often overlooked, yet it has a great influence on the quality and variability of the product. Inadequate removal of overburden from the mineral deposit often can be the source of excessive variation.

4.2.1.2.2. Drilling and Blasting

Except where unconsolidated deposits are being worked out, such as old river-beds, which are a source of boulders, gravel and sand, the first operation in the production of aggregates is blasting. Depending on the requirements of each operation and specifically the blasting pattern, blasting results in a spread of loose rock ranging in size from typically 400mm to zero, although the top-size of the run-of-mine ore can be up to one or two meters. Quarry operators commonly design fragmentation shots for safety, economy, ease of use at the primary crusher, and even public relations, but they often forget about quality. It is important that the shot layout be properly engineered, documented, and adhered to for maximum consistency. Varying the shot pattern can mean changes in product size throughout the operation. Smaller shot rock, resulting in less crushing in the secondary and tertiary stages, may mean less improvement throughout crushing. Therefore the mineral quality and/or changes in physical properties of the product may be affected. Whole detonation-sequencing and blast intensity also must be properly engineered. Size changes resulting from installation to detail can have the same effects as mentioned above. Also, an erratic blast that throws the shot rock over a large area will tend to cause variation in size gradation that is delivered to the primary crusher. Any deviation from previously established shot patterns, sequencing, and intensity should be carefully thought as to the effect on product quality. Geologic variability in the deposit can sometimes affect sizing but more often will cause a change in mineral integrity and physical property.

4.2.1.2.3 Crushing

In stone quarries large material usually is reduced in size by either a jaw or a gyratory crusher. After primary crushing, the resulting aggregate generally will be placed in a large “surge” pile where it can be fed into the secondary operation whenever convenient.

Care must be taken when building up and loading out surge piles, as this step can be a major source of segregation of material going to the secondary plant. Variation at this point may affect both mineral quality and gradation. Care should be taken to thoroughly mix the older material a little time with fresh product to make the surge as uniform as possible as it is being pushed into the tunnel. Secondary and tertiary crushing, if necessary, are the final steps in reducing the material to a desired product size.

4.2.1.2.4 Screening

The best technique for gradation control is screening. Screening is a technique used to control both quality and gradation of the aggregate product. If deleterious material still exists at undesirable levels after crushing and can be identified as being predominantly in one size range that is not needed for product size, it may be screened out. Washing for example, may be necessary to clean a concrete aggregate. Frequent checking of gradation should be a standard operating procedure. Sometimes screening variation is too great even under the most favorable of conditions. The most common reason for high screening variability is the tendency to push too much material over a screen. The only way to maintain a bed of material thin enough for optimum efficiency is to provide enough screening to allow the desired rate of production. For well-graded products, gradation control may not be accomplished without separating the material into fractions. Frequent sampling, testing and control charting are necessary for monitoring, because aggregates gradation is subject to so many variables.

Fig.3.1. Coarse aggregate production Standard plant [7]

4.2.2 Standardization in Aggregate Production

4.2.2.1 General

Standardization is defined as a model or general agreement of a rule established by authority, consensus, or custom, created and used by various levels of interest. The setting of the standard depends on the effect the dimension variation has on the performance of the product. Standardization is required not only for ensuring procurement of the right quality of incoming material, but also for cost reduction. The aim of standardization should be to have uniform standards for similar items, and the standard evolved should take cognizance of the indigenous availability of materials to the maximum extent possible.

4.2.2.2 Benefits of Standardization

The important general benefits are as follows:

1. Standardization helps reduce inventory items on site.
2. It helps in evolving better means of communication about the material being considered.
3. It forms a base for further inventory analysis.
4. The specification of items can be more clearly spelled out, making quality control firm.

By using national standards, it is easier to locate sources of supplies. The importance of standardization in the construction industry especially for construction materials cannot be over emphasized. Industry has become increasingly interested in assessing its economic efficiency, and thus is more interested in the role of standardization. Systematic and reliable results can be attained on a common basis.

Fig.3.2.Shows Standard Handling of Aggregate Production [7]

4.2.3. Aggregate Production and its Environmental Impacts

The aggregate industry is presently facing a growing, public awareness in relation to the environmental profile of its activities. Important areas of concern are:

The non-renewable character of the natural resources, especially in regions facing a coming shortage of adequate local materials,

The environmental impact on neighborhood and of the quarrying and of the materials transport related to the quarrying activities,

Land use conflicts between quarrying and e.g. agriculture, recreation, building sites, archaeology - especially in densely populated regions,

A lack of sustainability in production, characterized by inferior mass balance (i.e. high percentages of e.g. surplus fines to be deposited) and a high energy consumption needed per. ton aggregate produced these questions in the relation between the aggregate industry and its surrounding society will by far be determinant for the industry's survival potential.

In the future, only those companies and branches who can earn their public acceptance from an active use of environmental parameters in their planning and execution of own activities, will survive. The real challenge here is to merge the environmental issues with the industrial ones; to create industrial plants, which are at the same time environmentally friendly and economically profitable, which integrate quarrying and industrial production, and finally – for which there exist plans for restoration and area use after quarrying period is completed.

4.2.3.1. Impacts of Quarry Sites on the Environment

Quarries are opened for production of construction material such as selected materials for roads construction, dimension stones for buildings, gravel, aggregates, ceramic and cement raw materials, etc.

The following are impacts on the environment due to aggregate production processes:-

- Ponds developed in a quarry can serve as breeding ground for water born disease and mosquitoes,
- Children who swim in quarry ponds could draw down and die and can be a threat to animals,
- The vertical cliffs can cause death to animals and human live, land slide and land fall, production of dust, overburden disposal accumulation, affecting farm land or cause land use change, etc.

4.2.3.2 Mitigation

- Restoration of the completed overburden disposal areas,
- Abandoned quarries should be cultivated and seeded and trees planted,
- Adopt the safest quarry opening method,
- Eliminate hazardous high walls
- Shooting down the high walls
- Cover by soil and re-vegetation
- Establish appropriate quarry drainage system,
- Rehabilitate quarries and refill irregular and level surfaces around quarry sites,

Mining designers must consider the effects of mine on its surroundings. Engineering alternatives have to be judged according to their environmental influence. After a plan is adopted, the effects on the environment should be monitored. Construction materials producers and communities should as a minimum recognize environmental management as a high priority, notably during the licensing process and through the development and implementation of environmental management systems.

Fig.3.3. Shows Impacts of Quarry Sites on the Environment [8]

4.2.4. Aggregate Production Methods in Addis Ababa and in around Area

4.2.4.1. Fine Aggregate

Natural fine aggregate or sand is dredged from river beds in most parts of Ethiopia. Finely crushed aggregate is also used in some parts of the country where natural sand is not available. In most parts of the country, though the quality varies significantly one from the other, fine aggregate is available abundantly at least for the present.

4.2.4.1.1. Sources of Fine Aggregates

As most of the Fine aggregate used in Ethiopia is from river beds, mostly fine aggregate is not produced in wet seasons. One reason for this is that since the river over flows in that period it would not be possible for fine aggregate producers to get into the river bed and collect the fine aggregate. The other reason is that most fine aggregate production sites are not accessible by vehicles in this period.

4.2.4.1.2. Production Methods

Fine aggregate production sites are not mechanized. The production is done by local people of the area using traditional method of collecting the fine aggregate from the river bed by donkey. And, depositing it to a place where vehicles can get in. Fig. 3.4 and Fig .3.5 show the primitive but the usual way of producing fine aggregate .Fine aggregate demands of Addis Ababa is met by fine aggregate produced in the same manner. Finally, the collected fine aggregate is loaded manually on dump trucks and is then transported to the actual site or concrete production plants and is directly used for actual concrete production or related works. The production method of fine aggregate in Addis Ababa and around area is so primitive that the fine aggregate produced in this manner is exposed to the following situations.

1. Since it is collected in a primitive manner by human labor using small hand tools, it is susceptible to a greater degree of non-uniformity; this non uniformity can be expressed by its gradation.
2. Since it is transported by donkey and collected somewhere in an unprepared ground, it is susceptible to contamination by deleterious substances.
3. There is no room for quality checkup.
4. There is no room for modern production of standardized product.
5. Most sand producers are local farmers who have no detail technical knowledge about the material they produce. The only knowledge they have doesn't go far from what they are informally heard from their product customers.
6. The local producers are quite numerous in a single local area that it is difficult to get consistent supply from a specific area.
7. Since the sand itself is naturally available material it is quite difficult to get a consistent supply from same location even in hour's interval.
8. There is wastage of material in the process.

Fig .3.4 Fine aggregate is being collected from river bed manually around Koka [7]

Fig 3.5 Fine aggregate being collected by human labor and being loaded on back of a donkey around Koka [7]

4.2.4.2. Coarse Aggregates

Coarse aggregate is produced in Addis Ababa and around area using aggregate crushers and by crushing manually using human labor and small hand tools. Especially, in rural areas and in construction sites where the coarse aggregate demand is low manual crushing is normally experienced. In addition, the crusher plants vary in size and production quality.

The summary of the general production technique followed by the plants is presented below.

4.2.4.2.1. Production Methods

1. Crushing by Human labor and Hand tools

Procedure

1. Boulders are collected
2. Very big ones are broken down, using sludge hammer and wedge, in to smaller units.
3. Very strong boulders are broken down after they are burnt for hours with high temperature using worn out vehicle tyres.
4. The broken relatively smaller boulders are then further broken down by hand /human labor/ using sledge hammers (1-3Kg.). Figure 3.6 shows boulders being further broken down into smaller pieces by human labor.

The following problems are associated with this method of production:

1. Production is by human labor which results high degree of non-uniform and inconsistent product. Especially, the gradation and shape of the aggregate produced will certainly be poor.
2. It is not up to the standard
3. Has problems associated with the production process

– Production is too little,

– Not convenient to quality control,

– Not feasible in places where relatively smaller boulders are not readily available,

– Difficult to rely on the quality and quantity produced by this process

Fig.3.6 Boulders for coarse aggregate preparation being crushed by human labor [11]

2. Low Scale Mechanized Crushing

1. Boulders are collected

2. Very big ones are broken down, using sludge hammer and wedge, in to smaller units.

3. Very strong boulders are broken down after they are burnt for hours with high temperature using worn our vehicle tires.

4. The relatively smaller boulders are fed in to the crusher and are crushed into smaller sizes. Figure 3.7 shows a small scale mechanized crushing plant.

Fig.3.7. Low scaled coarse aggregate crushing plant [11]

Problems associated with this method of production

1. Production is relatively small and it is not reliable both in respects of quality and quantity
2. The raw crushed stone is prepared by human labor which results high degree of non-uniformity and inconsistency of the product. Especially the gradation and shape of the aggregate produced is quite poor. Flaky aggregate particles result from this mode of aggregate production. In addition, it is not feasible in places where relatively smaller boulders are not readily available.
3. Quality- The boulders they usually use for production are so weak that the resulting product becomes of low quality. In addition, it is not convenient to quality control.
4. It is not up to the standard

3. Medium to Large Scaled Crushing Plants

These types of crushing plants use open pit quarrying method of aggregate production. They have the following characteristics.

1. Have big plots of land and are usually established after some geological investigation is carries out in the area especially in the availability, potential and to some extent to the quality of base rock suitable for coarse aggregate production.
2. At the beginning of the production process, the over burden is removed and the area is made ready for drilling before the actual process of blasting is started. This step involves stripping the overburden and exposing the bedrock for blasting. Here selected materials production is carried out in the meantime.
3. Usually boulders are produced from the existing big alluvial stratum/bed rock by a process of blasting.
4. Blasting is usually carried out using explosives. In order to carry out blasting holes for explosives are drilled using Wagon Drilling Rigs and Manual Perforators at a certain calculated distance.
5. Dynamites are inserted which are connected with detonating cord relay and safety fuses attached at the end of the explosion.
6. Blasting is then carried out by explosives, ammonia nitrate or gelatin 30.
7. The resulting rock is again blasted if it happens that it is too big for the continuing production process and this process is called secondary blasting. After the blasting is carried out, the blasted rock is collected using excavators and is loaded on dump trucks using loaders preferably chain loaders.
8. The resulting crushed rock is then further crushed using Dozers. The crushed rock is then sent to the crushing site by a dump truck and stock piled.
9. The stock piled crushed rock is then fed to the crusher and will further be crushed in to rather different smaller sizes.
10. Using separators, which are usually three or more, the crushed rock is stock piled and becomes ready for use.
11. Finally it is loaded on dump trucks and is then transported to the actual construction sites.

Figure 3.8 shows one of the biggest aggregate production plants in Addis Ababa.

Fig.3.8. Large scaled coarse aggregate production plant (Blue Nile -around Kaliti) [7]

Comparison with other methods of production

1. The production system is controlled
2. The gradation of the resulting aggregate is relatively good and convenient for quality control
3. Carried out by a relatively trained personnel
4. It has a reliable supply
5. High production capacity per day
6. Has high environmental impact
7. Convenient for production of standardized product

4.2.5. Environmental Impacts of Aggregate Production Plants in Addis Ababa and Around Area.

Quarries are opened for production of construction material such as selected materials for roads construction, dimension stones for buildings, gravel for aggregates, raw materials, etc. However, quarry operations have impact on the surrounding environment. Especially, the environmental impacts of aggregate production plants which are located in and around cities cannot be underestimated. Aggregate production plants in and around Addis Ababa are good examples. The discussion made in this section concentrates on the situation of aggregate production in Addis Ababa. One of the environmental impacts that aggregate production plants have on the environment and on the inhabitants dwelling nearby are the dust that results while crushing the aggregate.

Fig 3.9.Shows dust produced by a process of aggregate production in one of the biggest aggregate production plants in Addis Ababa.

Fig. 3.9. Dust produced by a process of coarse aggregate production (Blue Nile)[7]

Most of the materials used in the Construction of cities have natural origin. In obtaining these materials there are a number of active and abandoned quarries which change the natural topography in Addis Ababa. Abandoned quarries are left open and some of them becoming ponds, or domestic waste is dumped to them which become favorable place for flies and other insects breeding. Unless old quarries are filled and planted with trees it would be difficult to avoid their hazardous consequences.

Fig 3.10. Impact of coarse aggregate production on the environment (The Addis Ababa City Administration Construction Materials Production Plant) [11]

Fig 3.11 Coarse aggregate crushing plants have effect on nearby inhabitants, schools, hospitals, factories etc. especially when they are located within cities [11]

Chapter Five:-Conclusion and Recommendation

5.1. Conclusion

Materials management is an important element in project planning and control. Further, one important aspect of materials management is handling of construction materials from quarry to construction site.

Aggregate being one of the important construction materials of many of the construction projects, in addition to its subjectivity to variability, requires a close and thorough care and management in construction projects. Coarse and fine aggregates are usually naturally occurring that they are subjected to a wide range of variability.

Coarse and fine aggregates constitute the majority of the volume of a concrete. Especially, fine aggregates are used directly from their source or quarry without given any kind of treatment that might help to keep them in line with standard quality requirements.

To analyze the situation of handling of concrete making aggregates in Addis Ababa this case study has been conducted and the results found are summarized as follows. The methods used for data collection were prepared appropriate questioner, material test data collected in laboratory and interview concerned personnel of AACRA.

It was observed in this case study that handling of fine aggregates in the Addis Ababa construction Industry context is not mechanized. Handling of these materials starting from the production process to the storing and use of the aggregates in construction sites is very poor. In addition, the quality control aspect is too weak that the specifications prepared and the tests required by supervising Engineers are too loose.

This is a result of two possible reasons. The first one is that there is no organized fine aggregates supplier in the country that the contractors have no choice except accepting whatever quality the supplied fine aggregates has. The second reason is that responsible government bodies and supervising engineers don't make tight control over contractors in the aspects of materials quality.

Handling of coarse aggregates in the Addis Ababa construction industry is no different from that of handling of fine aggregates. Quarry site selection is usually done without prior detail site investigation and assessment of the availability and properties of the bed rock. In addition, future expansion of nearby towns and environmental impacts of the crushing plant are not usually taken in to consideration in locating the quarry site. This has resulted in wastage of resource and unnecessary expense in addition to the environmental impact it has imposed.

The other important aspect with respect to production process of aggregates is environmental impact of aggregate production plant. This research has shown that the aggregate production plants in Addis Ababa have significant impact in their surrounding environment. In addition the effort that responsible statutory bodies are making towards controlling the production plants with respect to environmental impact is too minimal. However, in the production process take all the necessary precautions and measures to avoid the environmental impact of aggregate production plants very important.

5.2. Recommendation

Fine Aggregates

1. Fine aggregate producers should be organized to produce fine aggregate which, in addition to its consistency, satisfies standard requirements.
2. The sand production method should employ modern technologies. Utilization of machineries like loaders and excavators in place of primitive labor based production should also be taken in to consideration. Screening plants should be established where fine aggregates are being produced especially in places where the quarry sites are relatively suitable for such plants and in places where the quarry plant is accessible to the nearby highway.
3. Responsible statutory bodies should impose standardization requirements on parties who are producing fine aggregates.

Coarse Aggregates

1. Thorough study before selection quarry sites should be given due emphasis.
2. Close control of the production process.
3. Site location and selection is very important.

Environmental Impact aspects

1. Creating awareness that quarry sites within the city and among settlements could be detrimental to people’s well-being and health and hence to look for other areas that could not cause much harm.
2. If there is environmental, social impact on the surrounding area, technical advice should be given to enable limitation of number of bore holes, stripping lines and extent of depth, amount of explosive material use etc. to make the development environmentally friendly.

3. Ensuring that the quarrying activity would not adversely affect the environment and society through precluding sustainable urban development.

4. Take urgent appropriate legal actions to safeguard the environment from inappropriate land management.

Standardization and Case study Aspects

1. Laboratories should check all qualities of aggregates to investigate their compliance to standards.

2. Quarry sites should be checked for standards. They should have consistent quality and quality assurance periodically. The customer should be able to compare quality of the aggregate without any expenses for tests.

3. Laboratory tests should be compiled periodically for further research works.

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